Boletim da Sociedade Astronômica Brasileira, **31**, no. 1, 112-113

Applying Artificial Intelligence for learning and fitting quasar 3C273 light curves

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Abstract. The aim of this work is to develop an learning algorithm based on Neural Network (NN) to learn the temporal behavior of a quasar better sampled light curves and apply these learning to less well sampled light curves, so it would be possible to infer the missing data on it. This approach has given good results so far with data been inferred with low root-mean-square deviation.

Resumo. O objetivo deste trabalho é desenvolver um algoritmo baseado em redes neurais que aprenda o comportamento de uma curva de luz de um quasar, aplicando este aprendizado em uma curva menos amostrada, de modo a inferir a ausência de pontos. Esta abordagem tem dado bons resultados, com dados inferidos com baixo desvio quadrático médio.

Keywords. Quasar 3C273 – data analysis – jets

1. Introduction

The object of this study, 3C273, was the first cataloged quasar, but have been monitored, in optical frequencies, long before it. It has a redshift of about 0.158, making it the closest quasar found so far, with apparent distance of approximately 760 Mpc. It emits energy in the whole electromagnetic spectrum, with an complex variability, which have been studied through observational campaigns from different radio observatories since its classification (Schmidt, 1963) . However, most of the campaigns wore not perform continuously, and there were gaps in the light curves. To model the light curve and fill it with data, we used a NN named LSTM, one of the most used Machine Learning Technique for Time Series (Goodfellow et al., 2016).

2. Methodology

NN, created in 1954, are the most used kind of machine learning technique. It was based on the brain's architecture, but after the understanding of the math that governs it, more complex architecture could be created. In 1997, the Recurrent Neural Network named Long Short-Term Memory (LSTM) was created. This architecture make use of one connection, called cell state, that carry information outside the normal flow, which can keep weighs information along the code for a longer period time (Deep Learning, 2018).

This research have made use of data from 3 different Radio Observatories: Michigan Radio Observatory (UMRAO) situated in USA and operating at 4.8, 8 and 14.5 GHz; Itapetinga Radio Observatory (ROI) in Brazil operating at 22 and 43 GHz; Metsähovi Radio Observatory situated in Finland and operating at 22 and 37 GHz.

3. Results

3.1. Radio Light Curves

The light curves in Figure 1 display the data from the observatories used in this work. We have chosen the big event reported, at Radio frequencies, in the beginning of 1990's. All Light Curves were shifted to coincide the peak from this event. Based on this we were able to follow the event through the frequencies. The day difference between the peak registered in different frequencies is shown in Figure 2.

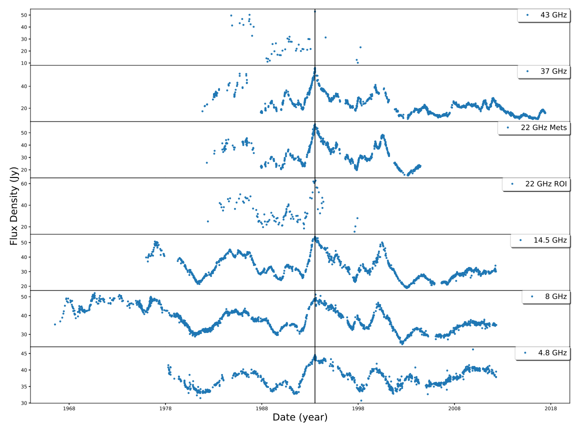


FIGURE 1. The figure shows the observed data used in this work. For data preparation, an shift was performed, adjusting the curves by a big event that occurred at radio frequencies in the beginning of 90's.

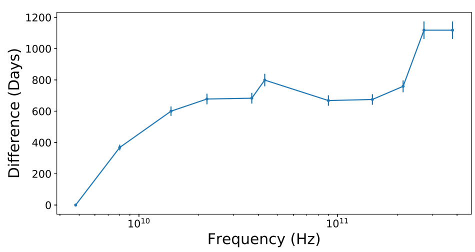


FIGURE 2. The figure shows the time difference between the peaks for two different events. The zero correspond to the date of the peak at the frequency of 4.8 GHz.

3.2. Preliminary results using the Neural Network

We have applied the NN in two ways. The firts one is shown in Figure 3. We used the NN to read the well sampled light curve from Metsahovi Observatory at 37GHz and learn the behaviour from 67% and model the other 33%.

The second approach, shown in Figure 4 was to use the well sampled lights curves as model and apply the learn to others not well sampled ones.

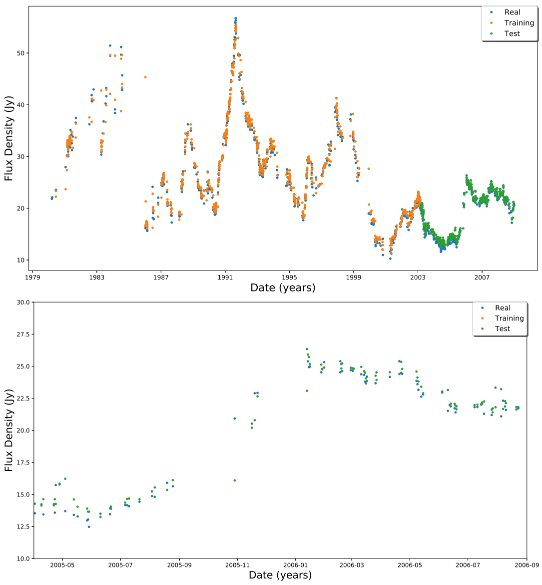
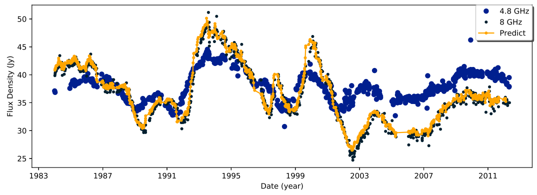
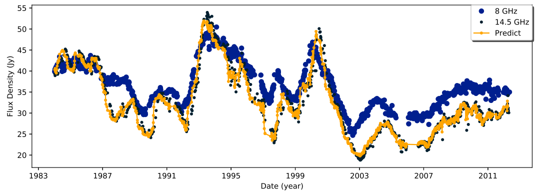


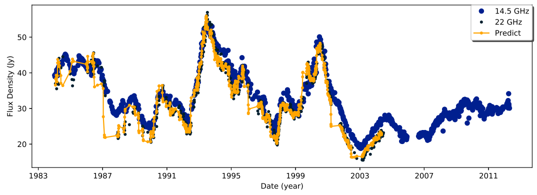
Figure 3. Panel a show the application of the NN to the 3C273 light curve at 37GHz. Panel b shows a zoom in the test set from Figure a. It has learned the behavior of the first 67% observations and applied the learning to the rest 33%.



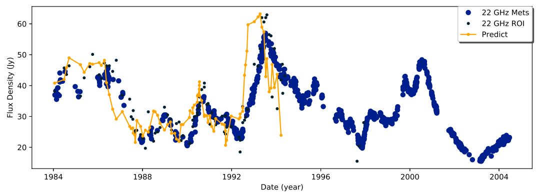
(a)



(b)



(c)



(d)

Figure 4. The plots a, b and c show the result of the application of the NN on a lower frequency light curve and the posterior application of the learned on a higher frequency light curve. The plot d shows the results of the NN on modeling from the well sampled Metsahövi's 22GHz light curve and to predict on the not well sampled ROI's 22GHz light curve.

4. Discussion

As reported by Marscher and Gear (1985), the events in this object occur latter in time and were attenuated at lower frequencies. We report the time difference between the maximum of the event for each light curve where it was possible to notice that this difference change abruptly between radio and millimetric bands.

NN are good options for predicting data in Radio Astronomy. So far, the NN worked well predicting data from the behavior of a single curve, and seems to be able to learn from an good sampled curve and predict on a not so well sampled as well.

Acknowledgements. This research has made use of data from the University of Michigan Radio Astronomy Observatory which has been supported by the University of Michigan and by a series of grants from the National Science Foundation, and from the Aalto University Metsähovi Radio Observatory and for that we thanks to the dr. Margo Aller and to Prof. Anne Lahteenmaki respectively for the data provided. I also thanks to CAPES for the scholarship and the Mackpesquisa for the financial support.

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